STRATEGY RESEARCH PROJECT

IN SUPPORT OF INFORMATION DOMINANCE: ACQUISITIONS AND ORGANIZATIONS

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In Support of Information Dominance: Organizations and Acquisitions

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ABSTRACT

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The purpose of this work is to provide a basis and a framework for today's command, control, computer, communications, and intelligence (C4I) acquisition policies that will ensure the military is positioned to support success on the 21st century battlefield. This paper establishes an approximation of future warfare and the changing nature of organizational structures by summarizing current published works. Resulting tenets for C4I operations are then developed. A summary of the technical constraints that are related to and important for the implementation of the C4I tenets are provided. Specifically considered are technology hurdles in bandwidth, computer technology, and software complexity. Finally, current and recommended acquisition policies that are applicable to the success of C4I architectures in support of 21st century Warfare are discussed.

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INFORMATION DOMINANCE:

ORGANIZATIONS AND ACQUISITIONS

"Knowledge will forever govern ignorance, and a people who mean to be their own governors must arm themselves with the power which knowledge gives." -- President James Madison to W. T. Barry on August 4, 1822.

I. INTRODUCTION

Within the past decade, our society and our Army have experienced an onslaught of automation, a revolution in information technology[1], and an ongoing evolution of our command and control and organizational structures[2]. The battlefield has become an environment demanding faster cycle times. Weapons systems have become vulnerable if observable and our missions have evolved to embrace a much wider range of engagements. These changes have exacerbated the urgent need for improved battlefield awareness, coordination, and speed. We must continue to design and equip our Army in such a way that takes advantage and control of information technology.

This paper will summarize projections and trends for 21st Century Warfare and organizations. Those trends will be reflected in both the Army's command and control organizational structure and the supporting information technology acquisitions. Important technical challenges to implementation of future command and control systems will be outlined. Given the problem of the changing conflict environment and the technical

constraints, recommended initiatives and policies are outlined that will enable the acquisition system to be best configured to support information dominance warfare.

II. THE 21^{ST} CENTURY AND TECHNOLOGY.

Both the military's organizational structure and the nature of 21^{st} Century Warfare will have profound effects on the projected needs, requirements, and nature of the C4I equipment that are required to support the military forces. In the first section, the organizational changes taking place within the Department of Defense and the changing style of warfare will be used to establish the environment for command and control requirements. The second section summarizes technical constraints that are important for the implementation of C4I systems.

A. 21st Century Organizations and Warfare.

The explosive growth of information technology has affected many facets of our lives to include the social structures forming the basis of our interactions. For example, executives, who ten years ago, would not operate a typewriter or computer keyboards are now managing much of their own correspondence[3]. The growing importance of e-mail and the Internet, to the point that they have become an integral part of the workplace, is another example. The people networks that have become an important part

of accomplishing our jobs[4] are also an example of the effects of information technology on the formation of networked organizations.

1. Organizations.

Information technology is driving a cultural change in the power structures of organizations. Hierarchies are flattening, leadership by consensus is on the rise, and interrelationships and interdependencies are providing an engine for success in both business and government organizations. This trend is evident in the writings of political scientists, militarists, and business leaders.

From political scientists, two examples are provided. Published in The New American Politician, Burdett Loomis quotes Congressman E. J. Patterson of South Carolina:

> "One of the problems around here (in Congress) is that people think of leadership in hierarchical terms. We need more consultative leadership."<5>

Jessica Matthews, a senior fellow at the Council on Foreign Relations in "New Perspectives Quarterly," states:

> Above all, the information technologies disrupt hierarchies, diffusing and redistributing power. By drastically lowering the costs of communication, consultation and coordination, they favor decentralized networks over any other mode of organization.<6>

The next two examples, from the military sector, are similar. Dr. Martin Libicki, of the National Defense University, writes:

> …one conclusion is inescapable. The days of the platform as the king of the battlefield are drawing nigh. With its eventual demise comes a similar demise of organizations built around such platforms and the systems used in acquiring them.<7>

A strategist and analyst at RAND, Carl H. Builder writes and lectures on the future implications of the information revolution.

> …the technology most disturbing societal order is the microchip… The order being disturbed is the one fostered or imposed by hierarchical organizations and institutions throughout human civilization… The microchip, by facilitating enormous increases in communications of all kinds, is making the control over information by and through hierarchies increasingly difficult.<8>

The response to the information technology revolution has been the most profound in corporate America. It is likely the market forces, the need to change in order to survive<9>, have driven companies to risk altered organizational structures with increased interdependencies. The results focus on value added processes for the business customer and an altering of preeminence from product to process.

Joseph H. Boyett in <u>Beyond Workplace 2000</u> describes a process-centered organization.

> Such an organization is customer-sensitive, knowledge-creating, and totally agile. It is flexible and adaptive, more like a living organism than a machine. It is an organization that can thrive on chaos, uncertainty, unpredictability, and continuous change.<10>

Boyett espouses elimination of layers of middle managers and supervisors. His process-centered organization is flatter, leaner, and most certainly not a hierarchy. TRACOR Aerospace's Circuit Board manufacturing facility in Austin, TX is an example of successful process engineering. This manufacturing facility has 63 employees, led by one supervisor. This facility, through application of process engineering practices, has realized a 27% increase in first time test yield of their product in 1994[11].

These examples are from three different fields of endeavor: the military, politics, and business. Experts in all three fields are drawing similar conclusions: organizations and leadership styles are changing. Organizations are flattening, looking more like networks than pyramids and leadership styles are evolving to more consultative or inclusive styles. These changes are enabled by three aspects of the information revolution: 1) the availability, quality, and quantity of information has increased, 2) the modes in which information is passed such as e-mail and the Internet have become simple to use, pervasive, and an expected means of communication, and 3) the advantages of an information-sharing approach in decision-making has become apparent and therefore the dominant leadership style. In the past, a leader with "too much information" was often tempted to perform "micro-management". However, due to the universal availability of information, it can no longer be used as a power base. Today's environment demands knowledge and

expertise be applied to that information. This represents a shift in power base from positional power to expert power.

These changes are fundamental and pervasive in our society. As a result, they will foster expectations within our military as a reflection of that society. The military must tailor its organizations and leadership styles to maximize the technological advantages for mission accomplishment. The battlefield environment will dictate some special considerations for military organizations. Nonetheless, the military is made up of individuals from the same society it serves and susceptible to the same technology forces that are changing that society.

An understanding of the sociological effect of the information revolution combined with understanding the future nature of warfare can be used to provide insight to the command and control requirements of future military forces. The next section will explore projections as to the nature of warfare in the 21st Century.

2. 21st Century Warfare.

The information revolution is affecting both the environment of warfare and the nature of competitive strategies for future armed conflicts. However, unlike the organizational trends identified in the last section where considerable consensus could be found, studies of future warfare trends are marked by adjectives such as unprecedented complexity, unpredictability,

and uncertainty. The Toffler's, in War and Anti-War [12], attribute some of this complexity to the fundamental changes taking place as a result of our continued evolution starting from a First Wave Agrarian Society to a Second Wave Industrial Society to the current changes taking us into a Third Wave Informational Society. They argue that this is only the second time in history that a true revolution in warfare has occurred.

With the demise of the Soviet Union, the global strategic environment has gone from a bipolar system to one that is no less violent and is much more complex. In addition to increasing complexities as power is distributed among more than two nations, the increased availability of information and knowledge is resulting in more open societies. These open societies are challenging the traditionally sovereign rights of nation states where there is evidence that power is further devolving to regional and local governments as well as to the private sector[13].

This global turmoil will give rise to a diverse range of conflict types. In the 1997 Annual Report from the Institute for Strategic Analysis,[14] conflict is categorized into five types spanning the intensity of the conflict spectrum from a global peer competitor to humanitarian motivated intervention into troubled states (see Figure 1). A single country's military configured to engage this array of conflict and peacekeeping activities will by necessity be flexible and agile. This range

of conflict implies a requirement for a full spectrum force which will include a mix of global strategic forces, heavy and light forces, and special operations forces[15]. At the tactical and operational levels the global environment will foster a battlefield that is more lethal, characterized by higher mobility, and one that will host an expanded battlespace[16].

Lethality will continue to increase both through improvements in munitions[17] and the ability to deliver firepower to the target with unprecedented accuracy. With the advent of Global Positioning Satellites (GPS) and subsequent worldwide distribution of GPS receivers, anyone or any weapon can know its location to within 10 meters. This technology alone has significantly contributed to precision strike capabilities.

Maneuver and mobility have always been an important warfighting skill from images of the Mongol horde sweeping down in a massive cavalry charge to the bewildered Iraqi forces as both the U.S. 18th Airborne Corps executed a sweeping flanking maneuver and the U.S. 7th Corps a brilliant double envelopment maneuver[1][18]. Mobility continues to improve as is evidenced with the tactical speed of the M1A2 Abrams tank and the migration of firepower missions to aerial gunships - the maturation of the helicopter. Improvements to command and control capabilities will also contribute to increased maneuver capability as maneuver

[1] Envelopment, either single or double is defined as taking a force around one or both ends of an enemy formation and then either attacking the enemy from the flanks or bypassing the enemy to reach other objectives.

implies not simply speed of movement, but the ability to place the firepower at the right time and place.

While increases in mobility and lethality will affect command and control techniques, the most profound changes will be as a result of growth in battlespace. A current symptom of increasing battlespace is evidence by command and control challenges presented by 1) the evolving Naval mission in "Littoral Warfare" and the associated coordination issues between Army, Navy, and Marine units, 2) the increasing range of Naval fighter aircraft and the associated coordination between Air Force and Navy who now share the same target set, and 3) the battlefield friction inherent in the management of the Fire Support Coordination Line (FSCL)[2]. The fundamental question is battlespace for airplanes or munitions, e.g., missiles? Some of the Army missile systems already operate in a battlespace in excess of the doctrinal FSCL.

Continued growth of the battlespace can be categorized into technology growth in two areas: seeing farther and shooting farther. Sensor accuracy, resolution, and the sensor platforms are no longer constrained by a two-dimensional battlespace. Sensor platforms have beaten ground level line of sight restrictions through increasing elevation and, as a result, will continue to proliferate on the battlefield. As the science associated with detector technology and computational power

[2] The FSCL is the line between Air Force and Army controlled battlespace.

improves, the resolution and accuracy of sensor platforms will continue to increase. The command and control required to manage this greater volume of engagement space at its temporally accelerated pace will represent challenges both organizationally and technically.

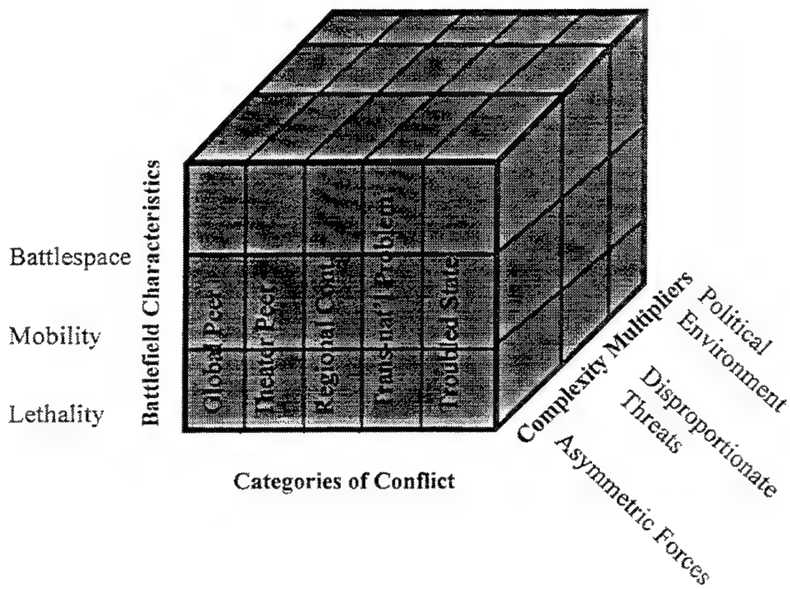

Figure 1. The Expanding Volume of Warfare.

The types of conflict combined with increasingly challenging battlefield factors; lethality, mobility, and battlespace, are further complicated by contributing factors such as asymmetric forces, disproportionate threats, and a political reality that demands short wars fought with international consensus and coalitions.

The future of warfare in the 21st century has been described as an increasingly challenging environment where complexities abound and technology advances will challenge our ability to control the environment. Figure 1, The Expanding Volume of

Warfare, can be used to simplify and visualize this environment in three dimensions with conflict categories on one axis, battlefield characteristics on another and complexity multipliers such as asymmetric forces, disproportionate threat, and political reality on another. The temporal nature of the "Warfare Volume," in which the battlefield and complexities are constantly changing, combined with the complex nature of the battlefield, will challenge our ability to command and control forces in this age.

The next section will merge the organizational trends and the estimate of 21st Century Warfare to determine the tenets for command and control systems of the future.

3. Tenets for Command and Control.

Section 1 surveyed results from three different aspects of our society: military, business, and political. All demonstrated evidence that organizations are flattening and that leadership styles are evolving from directive to more consultative or inclusive styles. Both indicate a growing need for denser connectivity between organizational elements. It also indicates a growing requirement for information gained from cross organizational boundaries. Connectivity across organizational boundaries is an approximate definition of interoperability.

The DoD definition of interoperability[19] is one of "connectivity and content". Interoperability is defined as, "The

ability of systems, units or forces to provide services to and accept services from other systems and to use the services so exchanged to enable them to operate effectively together." Within the services, advances in common data elements as well as common situational awareness have significantly contributed to improved interoperability. Interoperability, however, is necessary but not sufficient. Battlefield increases in mobility, lethality, and battlespace will require a level of interaction that can only be achieved through synchronization and simultaneity. The Army's 1997 Annual Report on the "Army After Next" describes interdependence as follows.

> Interdependence suggests the need for a level of interoperability between land, sea, and aerospace mediums that will allow a near simultaneous application of precision fires and maneuver applied in a broad pattern of effects that strike and check the enemy everywhere he can be seen and engaged.<20>

Underpinning the tenets of interoperability and interdependence is an increasing flow of information. However, information as a tenet may lead us down the alluring path of "more is better". Knowledge as a C4I tenet of operation is more descriptive of the requirement. Ervin J. Rokke, Lieutenant General, USAF, President, National Defense University[<21>] describes battlefield knowledge as "the ability to understand what we see and act on it decisively." By this definition, knowledge, fueled by the flow of information, builds on the understanding achieved through interoperability to provide the

ability to act on relevant information. The fusion of information into a useable set of facts that are understood and acted upon through the interoperability of systems constitutes knowledge. Interoperability that enables the simultaneous application of precision fires and maneuver is an interdependent system.

Pervasive throughout the discussion on battlefield environments has been a sense of urgency or a sense that the tempo of the battlefield has been increasing. Joint Vision 2010[22] and its Expansion[23] describe the battlefield in terms of four operational concepts: Dominant Maneuver, Precision Engagement, Focused Logistics, and Full-Dimensional Protection. Threaded throughout the explanation of each of these are phrases such as, "decisive speed and tempo" (dominant maneuver), "responsive and accurate" (precision engagement), "rapid response and distribution" (focused logistics) and finally, full-dimensional protection which includes such time sensitive actions as the in-flight intercept of incoming missiles. Shortening the timeline from sensor to shooter, the rate at which engagements are prosecuted within the battlespace, and our ability to get inside the "enemy's decision loop" are all examples of requirements for increased speed.

Table 1, C4I Tenets of Operation, is a summary of the four fundamental characteristics of a C4I system of the next century. These tenets of operation have followed from the discussion on

evolving organizations and emerging battlefield environment of the 21st century.

Brief Description and Summary C4I Tenets of Operation		
I.	**Interoperability**	Connectivity and Content
II.	**Interdependence**	Synergistic and Simultaneous Fires and Maneuver
III.	**Knowledge**	Information that is Understood and Acted Upon
IV.	**Speed**	Battlefield Tempo

able 2. C4I Tenets of Operation.

This chapter represents the problem statement for C4I policies and acquisitions: how to best configure acquisition policies and procedures to optimally support, at minimal cost, the future battlefield environments and organizations. The next section will highlight some of the constraints to implementation of the tenets of C4I operations.

B. Constraints on Implementation.

Given a technology, is it possible to efficiently engineer or manufacture that technology? This section will address some of the technical constraints that are important for implementation of the C4I tenets of operations.

1. Information Transfer

There are three transport media for signal transmission: wire, fiber, and free space. Recent research results indicate

that we are close to being able to deliver 10^{12} bits per second over fiber-optic cables.[24] That is approximately one million channels of TV concurrently. If that is too limiting, more fiber can be installed. The bandwidth of fiber is, therefore, nearly unlimited. Unlimited, but not the answer for a mobile, lethal, and highly maneuvering military force. The only remaining solution is then free space.

Spectrum management will continue to be a challenge on the battlefield. Both physics and politics are working against increases in available bandwidth. Spectrum sell-off of military frequencies in both the U.S. and other countries continues to squeeze the military useable bands.

The physics limitations on bandwidth are dominated by atmospheric absorption and attenuation. These effects begin to significantly reduce signal strength at frequencies above approximately 3 GHz[25]. In addition, high frequency line of sight communication also has attenuation effects as a result of foliage and obstructions that can lead to reflections of the signal or multiple paths for transmission[26]. These physical effects provide an approximate upper bound for frequency transmissions within the atmosphere. Since the operating frequencies are bounded by physics, the bandwidth available for terrestrial applications is also bounded and therefore limited.

Signal bandwidth is an indicator of the amount of information that may flow over a channel. Coding and data

compression techniques provide a multitude of clever ways to squeeze more knowledge into a slice of bandwidth. But they too have bounds and limits.

C. E. Shannon in 1949[27] derived an expression relating channel capacity to bandwidth and noise. For large bandwidths and power limited channels, the capacity levels off and approaches a limiting value. The implication is that there exists a limit on the rate at which one can transmit error-free over a power-limited channel[28]. No amount of clever coding can beat that rate. In fact, most codes are considered efficient if they can operate at one-half the channel capacity.

Shannon's concept explored the effect of channel noise on transmission capacity. Data compression techniques take advantage of different aspects of signals, their redundancy, and predictability. Redundant information in a message uses extra bits and therefore reduces the amount of information that can be transmitted within a given amount of bandwidth[29]. For example, if only 8 commands were required then a commander could send the complete plan using only 3 bits[3]. However, if the command to be transmitted was coded in standard ASCII of 8 bits per letter, then "attack", for example, would require 48 bits. It is the difference between 3 bits and 48 bits where many types of data compression techniques take advantage of redundancies in signals.

[3] The math being $2^3=8$. The exponent "3" is the number of bits required.

Another way to compress a signal is to consider its predictability. In the example above, the possibility of only 8 commands was highly predictable. If it was known that 90% of the time, the command was "attack", then the transmission could be reduced to sending bits only when the command was not "attack". Using statistical methods to reduce the amount of bits necessary to represent information is another approach that is often used to obtain data compression.

Both of these approaches to data compression, redundancy, or predictability suggest that there exists a fundamental limit on the amount of compression for a given signal type. Compression techniques cannot exceed the basic amount of information inherent within a signal. Theoretical bounds exist that show there are indeed limits to the amount of data compression[30].

Bandwidth, coding, and data compression all have been shown to have limits. The physical capacity to transmit information in free space is bounded. These bounds will have an effect on implementation of C4I concepts or architectures. Specifically affected will be the degree of interoperability, the timeliness and density of potential interdependence, and the amount of knowledge that can be exchanged.

2. Technology Growth Rate

A common criticism of the Department of Defense acquisition process is its long acquisition cycle - ten to fifteen years.

This is inappropriate for information technology systems as well as for the information technology parts of major weapon systems. Figure 2, Processor Performance Trends, shows that microprocessor performance doubles about every 18 months[31]. While the microprocessor is only an indication of computer performance, it is a strong indicator that technology growth is proceeding more rapidly than our acquisition timeline.

However, the increase in microprocessor performance also has limits. Currently, manufacturers have been able to increase performance by decreasing the line widths within the chips thus making it possible to fit more chips in a given area. More chips causes more complexity, resulting in greater performance. The next generation, beyond Merced, will require a change in process to continue to decrease the line widths. The new process, X-ray lithography, has some difficult engineering challenges. Manufacturing a durable chip template that can withstand a fast, repeatable process of making thousands of copies of a given microprocessor chip is problematic. The small tolerances required for the accuracy of mask placement are also an engineering challenge that will limit the number of chips within a given area[32]. Within 2-3 generations of X-ray lithography, line widths will again require a change of process. This time the line widths will be so small that quantum effects[4] will begin

[4] In this realm, the line widths are so small that the effect of individual atoms take precedence and therefore, the interactions between atoms becomes the driving force.

to take control of the process. This will be much harder to overcome.

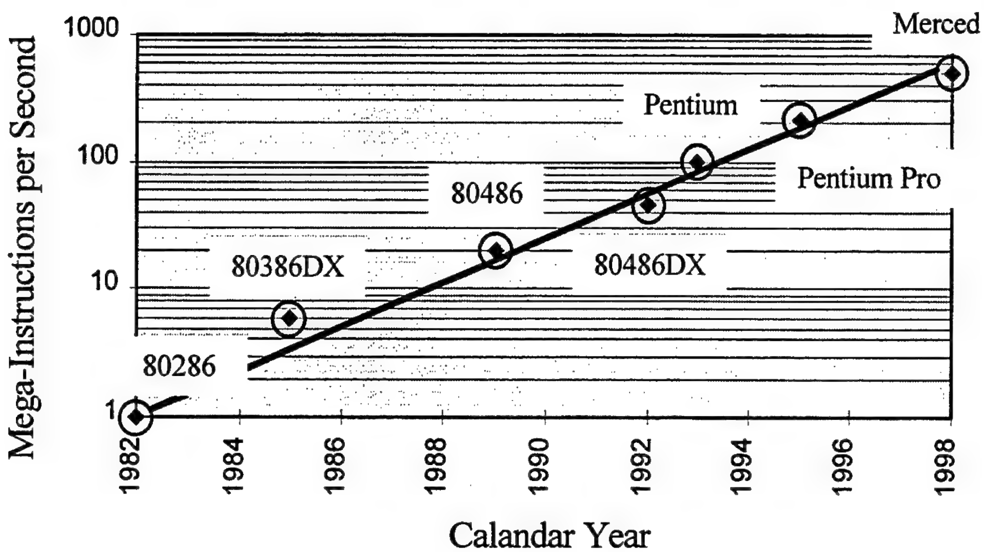

Figure 2. Processor Performance Trends.

Without the ability to continue to decrease line widths, the growth rate of microprocessor speed will be dampened. Microprocessor performance will still continue to improve but at a slower rate. Manufacturers can increase complexity by increasing the number of layers of circuitry that can be built on a single chip. Clock speed increases also can result in improved computer performance. Clock speed, however, is eventually limited by the speed a circuit can switch - a physics limit based on internal capacitance which acts like an inertial force to preclude instantaneous change. However, computer performance can continue to be enhanced through alternative architecture schemes

that allow various methods for interleaving multiple clocks <33>[5]. Some of these architecture improvements, however, may require a higher level of complexity in the software.

Nevertheless, the current DoD acquisition timeline will still not be fast enough to keep pace with microprocessor technology growth rates. Command and control requirements must take into account that massive computing power is not unlimited due to the imminent limits on clock speed and processor growth. A balance must be attained between limited transmission capability and the potentially available computing power. Centralized versus decentralized command and control structures are the issue. A balance between a highly interconnected structure with intelligent processing nodes versus simple nodes sending raw sensor data must be realized. Neither extreme is desirable nor attainable given the limits of computing power and bandwidth. However, a balance that optimizes the technology with the desired interoperability, interdependence, knowledge, and speed is required.

3. Complexity: Software Development

Amidst the dawn of the information age exists a necessary and pivotal cottage industry - software development. Software development today is like the making of Winchester Rifles was at

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[5]IBM is touting a new computer chip with a processing speed of 1,000 MHz. This speed was possible through

the end of the 19^{th} century. The design was set, as are software development principles, but each rifle's parts are made individually and pieced together by hand[6].

Measuring software productivity by lines of code can be an indicator of performance. A way to look at progress in software production is to measure the software expansion factor which measures the ratio of the number of lines of code written by the programmer to the number of lines of assembly code. The higher the ratio, the more efficient the coding process. Figure 3, Trends in Software Expansion[<36>], shows that the expansion factor has doubled every three years. Since microprocessor performance doubles every 18 months and software expansion only doubles approximately every three years, there is indication of a lag in software development capabilities with respect to hardware capacity. As a result, the expectation for software development programs may exceed the capability to produce that level of complexity.

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interleaving and merging existing functions[<34>].

[6] It was Eli Whitney, most famous for his cotton gin, who first engineered the making of rifles using standard, interchangeable parts. [<35>]

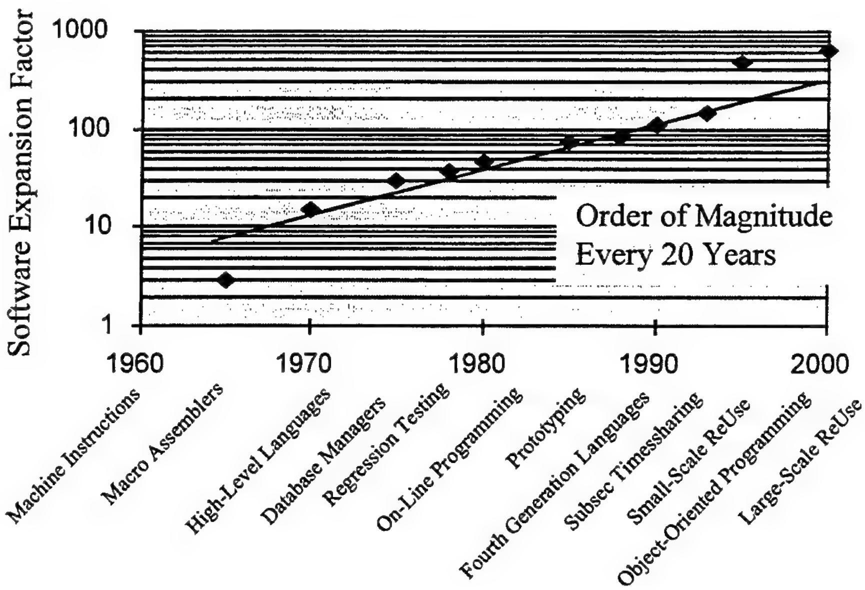

Figure 3. Trends in Software Expansion.

Frederick Brooks, Jr., in The Mythical Man-Month[37], asserts that the problems of software development originate from its essential complexity and the nonlinear growth of that complexity as the size of the software module increases. Brooks explains that defining requirements and describing the conceptualized solution is what takes time and talent. The approaches that would generate most progress are: reuse software, concentrate on the iterative extraction and refinement of product requirements, and nurture the great designers[38]. Reuse is desired but rarely attained due to requirements volatility and accretion. The slightest change in the reuse software module drives the cost of that software module up to 60 percent of the cost of module development [39].

Until software development evolves to where massive reuse is common and affordable, and to where programming language is advanced enough that the system design engineer is also the code writer, software complexity will continue to be a major factor in program cost and schedule. Prudent design of our 21st Century C4I architecture will be necessary to ensure that a software development bottleneck is not inadvertently planned into the product. Software complexity that exceeds our capability to manage can be an expensive hurdle to overcome.

This section has highlighted three technology areas; bandwidth, computer growth, and software complexity. While each of these areas has seen prodigious advances, each is marked by physics, engineering, or complexity hurdles that will impede its advancement. These technology hurdles will all have a major impact on the type of C4I architecture that can be implemented in the 21st century.

The last chapter will combine the 21st Century C4I operational tenets with the technology limits outlined in this section to explore the acquisition policies and practices necessary to support a 21st Century C4I architecture.

III. ACQUISITION POLICIES AND PRACTICES

The acquisition system that supports transition from an industrial based military to one that is dominant on an information age battlefield will be marked by rapid acquisition

and fielding of highly interconnected, custom- tailored products. This section outlines some of the initiatives that are applicable to C4I systems acquisition and, in particular, those that will be pivotal to the success of information technology acquisition in the 21st century. The fundamental paradigm for acquisition in the 21st century is a rapid acquisition cycle and the adoption of acquisition policies that support the reduction of the acquisition timeline.

A. Truncated Acquisition Timeline

Industry's timeline from concept to market is generally an order of magnitude shorter than the Department of Defense (DoD) acquisition timeline. The upper half of Figure 4, Acquisition Timeline, depicts the current acquisition cycle as specified by DoD Regulation 5000.2-R[7].[<40>] The fundamental difference in the industrial acquisition cycle is in the point at which the industrial cycle starts and finishes.

Industry would not develop a product that required excessive "Program Definition and Risk Reduction (PDRR)" due to cost and risk. Private industry has the ability to choose when to "harvest" a technology for insertion into a product and as a result skips most of the traditional DoD concept development phase and nearly all of PDRR phase. Unlike the military, a profit-oriented business has a great deal of latitude in its

choice of product, market, and timing. However, changes in the military requirements process could achieve a closer match between technological reality and military need thereby allowing the military to "harvest" technologies more appropriately.

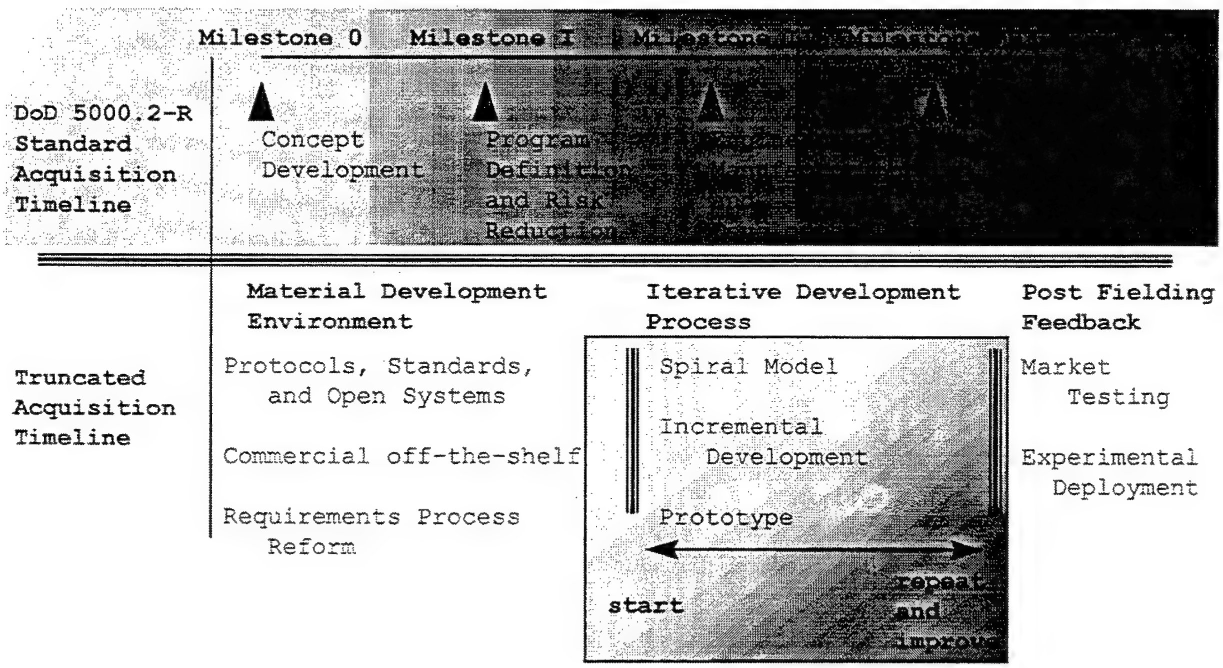

Figure 4. Acquisition Timeline.

On the fielding side of the cycle, industry does less system level testing than DoD. For example, software is released in beta versions and new model cars are often incrementally improved over several year's offerings. This is indicative of an industry-wide quality and testing philosophy<41>:

1) quality is inherent in the product, it is not a result of testing-prevention rather than detection,

[7] While the standard cycle is shown, it is important to note that the regulation encourages tailoring of these milestone decision points.

2) feedback from the customer is expected to result in product improvement, and

3) continuous review of critical process points, corrective actions, and outcomes is part of continuous process improvement.

The shaded portion of the lower half of Figure 4, Acquisition Timeline, depicts a truncated acquisition process that is similar to the business or profit model. However, since DoD does not have market forces to police the efficiency of the cycle, it must compensate with other incentives such as policy, process, and rewards, for both contractors and government organizations. The next two sections will outline the environment necessary to implement the truncated acquisition timeline.

B. Material Development Environment

The military and civilian sectors have many functions in common when it comes to computers and communications devices. This fact alone can be capitalized on to enable the effective and efficient acquisition of commercial off-the-shelf (COTS) equipment. Modification of COTS hardware is often costly and as a result should be minimized. Policies and process to reduce the DoD appetite to tweak existing equipment must be enforced. Two areas that must be monitored to continue to improve the efficient use of COTS: 1) requirements reform and 2) a continually

vigilant policy enforcing the use of standards and protocols in military systems.

1. Requirements Reform

The linear process of establishing a requirement based on a warfighting need followed by a material development process has a certain neat, organized, and alluring feel. This process was acceptable when the budget was available. However, we can no longer afford to develop unique military information technology equipment to satisfy "visionary" requirements that may not have a basis in available technology.

The battle labs have done a great deal to mitigate the problem of technology to requirements matching, but it is not enough. The requirements system must become a full partner with the acquisition system in its responsibility for cost, schedule, and performance. This requires organizational changes that establish a structure such that "acquirers" and "requirers" are responsible for the same goals.

The requirement versus performance trades must also be facilitated at a much lower level. Modification of the Operational Requirements Document (ORD) must be delegated to the Integrated Product Team (IPT) level that has the intimate information and responsibility for the cost/performance impacts of each specific requirement. In addition, for those requirements that can be satisfied by COTS, the ORD should become

only a guideline in order to efficiently buy COTS. Available equipment should be matched to the requirements document as closely as possible. Unfulfilled requirements must be closely scrutinized for criticality of need as they can represent costly redesign.

2. Standards and Protocols

A C4I architecture built on the fundamentals of interoperability, interdependence, and knowledge transfer must be inundated with transparent, seamless interfaces. Adherence to protocols and standards are a key to a seamless information architecture. As we evolve to more dispersed, highly interconnected command and control structure, the importance of interface management will become paramount.

The Joint Technical Architecture has been a step forward in the cataloguing of common interface standards, system protocols, and the DoD common data dictionary. Standards and protocols can accomplish information flow, but adherence to the DoD common data dictionary is crucial to achieving the transfer of knowledge. The dictionary provides the common language or vocabulary that is so necessary for effective communication.

There are three issues that bear continued emphasis and vigilance in this area: 1) the use of commercial standards in military hardware, 2) timely retirement of old standards/ protocols, and 3) the availability and use of open/systems and

standards. The JTA is committed to the reduction of military specific standards. This is vital to the DoD ability to capitalize on technology growth in the civilian sector. Since DoD must insert information technology into its systems in order to keep pace with the information technology growth rate, those systems must be able to accept current commercial standards. The JTA document must be closely monitored to ensure that outdated standards are removed.

An acquisition environment that encourages the use of COTS for information technology solutions is one that can lead to rapid technology growth rates for military systems and the necessary interoperability and interdependence for the 21st century. Requirements reform and strong standards and protocol policies are enabling factors for COTS procurement.

C. Iterative Development Process

Rapid acquisition is the art of harvesting technology when its ripe while meeting current customer requirements. Joint Vision 2010[42] and its Expansion[43], Operational Requirement Documents, and C4I architectures provide the framework for understanding the systems that are needed. The JTA provides the guidelines for technical standards that enable interoperability. What remains is to craft an acquisition system that is **routinely** responsive and agile for information technology solutions.

The lower half of Figure 4, Acquisition Timeline, depicts a much shortened procurement cycle based on spiral development incorporating prototyping and soldier assessment as its fundamental guiding principles. The Army's Warfighting Experiments (AWE) and Force XXI digitization of the battlefield have been the model acquisition cycle based on an iterative and incremental approach. DOD 5000.2-R must be changed to reflect this shortened, iterative cycle as the norm or the expected process. The traditional cycle will then become the exception and used only when absolutely necessary to achieve results.

IV. SUMMARY AND RECOMMENDATIONS

A. Summary

This paper has summarized current projections for 21st century organizations and warfare, and applied those results to technology constraints and acquisition solutions. Organizations are flattening, looking more like networks than pyramids and leadership styles are changing from directive to more consultative or inclusive styles. Warfare in the 21st Century has been described as increasingly challenging with increased lethality, mobility, and battlespace. These trends will be reflected in both the Army's command and control structure and information technology acquisitions that support it.

This work established a link between future organizations and the increasingly complex battlefield environment to four tenets

for C4I operations: 1) interoperability, 2) interdependence, 3) knowledge, and 4) speed. These tenets form the basis for C4I policies and acquisitions.

Three technology areas: bandwidth, computer growth, and software complexity, will have pivotal effects on the implementation of the four tenets of C4I operations were outlined. While each of these areas has seen prodigious advances, each is marked by physics, engineering, and/or complexity hurdles that will ultimately impede its growth. A requirements process tempered with an understanding of the technology hurdles will be necessary in order to craft a C4I architecture that is affordable and achievable.

The final chapter concludes with acquisition policies and practices that support implementation of the C4I operational tenets. The fundamental paradigm for acquisition in the 21st century is rapid acquisition and the adoption of the supporting acquisition policies.

B. Recommendations

The current environment of experimentation established by the AWE and Force XXI programs affords an opportunity to test the acquisition and organizational changes recommended in this work.

Recommendations as follows:

1. Implement organizational changes that establish a structure such that "acquirers" and "requirers" are

responsible for the same goals. As a prototype, detail TRADOC combat development personnel to the project offices to better coordinate trades between requirements, cost, and schedule. Empower those individuals to make ORD changes as necessary to implement cost and schedule trades necessary for product realization.

2. Continue vigilant enforcement of commercial standards and protocols in military systems.
3. Change DOD 5000.2-R to a spiral model as the standard process. The traditional linear cycle is then the exception and used only when necessary to achieve results.
4. The military must tailor its organizations and leadership styles to maximize the technological advantages for mission accomplishment. In the support and bureaucratic part of the Army, root out and abolish multiple layers of oversight. These are unnecessary layers of management. In the tactical Army, exploit the AWE environment to investigate reduction of command layers on the battlefield.
5. A balance between a highly interconnected structure with intelligent processing nodes versus simple nodes sending raw sensor data must be realized. Reinforce the Army's requirements process with technologically savvy personnel to enable an architecture that will optimally match

technical capabilities to warfighting needs. This enables the Army to "harvest" technology efficiently.

V. CONCLUSION

Society, warfare, and technology are all in a state of flux. Organizations, to include the military, are evolving to take advantage of the information era society. Warfare is more lethal, more mobile, and encompasses a larger battlespace. The C4I architecture that supports this complex scenario must be highly interoperable, massively interdependent, knowledge pervasive, and very responsive. In addition, information technology growth is continuing, software development is lagging, and there are limits on the amount of information transfer possible on the airwaves. Acquisition procedures must continue to accelerate the pace of technology insertion to enable the command and control structure necessary to support the military of the 21st century.

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